Science for College and Careers:
A Resource for Developers of the Next Generation Science Standards

ACT, Inc.

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Introduction

Within the changing global economy, the United States' economic competitive advantage increasingly depends on the innovation and productivity of its labor force. While the U.S. remains the world's science and technology leader, other countries are rapidly closing the gap and the U.S. is losing its scientific competitive advantage. Simultaneously, a substantial portion of the current U.S. science and engineering workforce is aging and needs to be replaced soon.

As a result, demand for a scientifically and technologically skilled workforce in the U.S. is high. The demand for scientifically and technologically skilled workers in the U.S. is projected to rise faster than the supply, leaving us unable to meet future science workforce demands. The number of jobs requiring science, engineering, and technical training in the U.S. increased by an average of 2.2 percent each year between 2000 and 2007, or nearly twice the rate of overall job growth (National Science Foundation, 2010). At the same time, the need for low- and semi-skilled jobs in the U.S. continues to decline, often as a consequence of automation (Carnevale & Rose, n.d.). The result, according to the Bureau of Labor Statistics (Lacey & Wright, 2010), is that 25 of the 30 occupations projected to grow the fastest in the U.S. between 2008 and 2018 are in science, engineering, health, or technology-related fields.[1]

Are our students being adequately prepared to become the scientifically and technologically skilled workforce of tomorrow? The level of science readiness of today's students indicates that the answer to these questions is no.

What is readiness for college in science? According to ACT's empirical definition (ACT, 2010b), it is the level of academic preparation a student needs to develop in high school to be ready to succeed in first-year credit-bearing science courses at a two-year or four-year postsecondary education institution. While not every student plans to attend college after high school, many of the jobs now being created in a highly technology-based economy require skills and knowledge equivalent to those expected of the first-year college student (ACT, 2006).

Based on ACT's College Readiness Benchmarks, most U.S. high school students are not ready for the science-related challenges they will face in college (ACT, 2011c).[2] Thirty percent of ACT®-tested high school graduates in 2011 were ready for college coursework in Biology (Figure 1). More students met ACT's Benchmarks in Mathematics (45 percent), Reading (52 percent), or English (66 percent) than in Science.

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[1] Occupation growth as presented is measured as percent change between 2008 and 2018, not numeric change, and as such, is reflective of a growth rate. For example, it is projected that there will be 53.4 percent more network systems and data communications analyst occupations in 2018 than in 2008.
[2] The ACT College Readiness Benchmarks represent the level of achievement required for students to have a high probability of success (a 75 percent chance of earning a course grade of C or better, a 50 percent chance of earning a B or better) in credit-bearing first-year college courses in English Composition, Algebra, introductory Social Science, and Biology (ACT, 2010b).

Figure 1: Percentage of ACT-Tested High School Graduates Meeting ACT's College Readiness Benchmarks, by Subject Area: 2011

Percent

Subject	Percent
English	66
Mathematics	45
Reading	52
Science	30

ACT College Readiness Benchmark
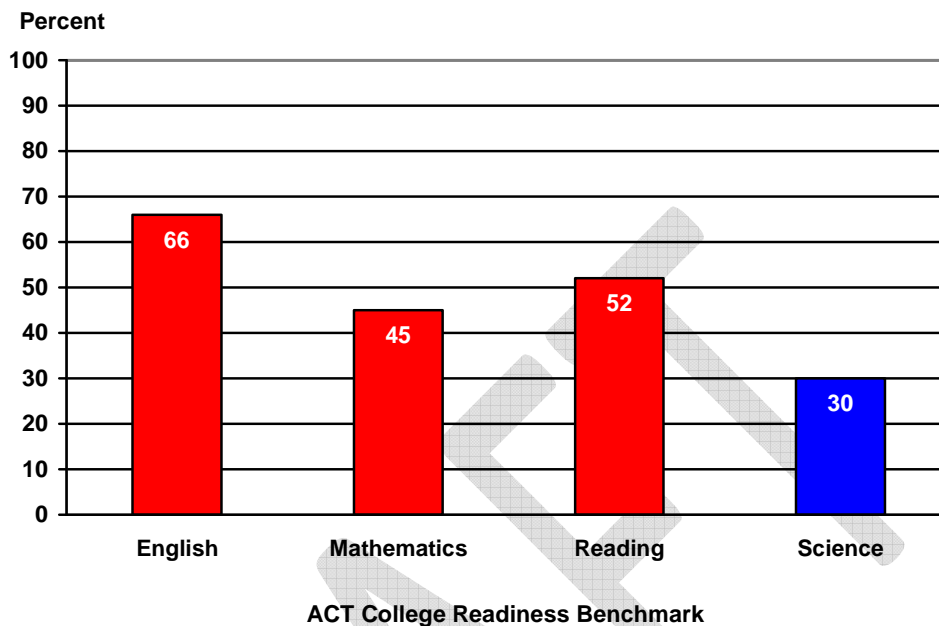
Despite the critical role science readiness plays in the success of students, this finding is not new. For decades, ACT research has shown that upwards of three-fourths of ACT-tested students graduating from high school each year have not been prepared to succeed in first-year college science courses. Similarly, data from ACT's WorkKeys® Applied Technology assessment show that only 22 percent of recent examinees score at or above the level needed to demonstrate scientific and technological competency for jobs that do not require a bachelor's degree but that offer a living wage for a family of four and opportunities for career advancement (ACT, 2011d).

Levels of science readiness also continue to be lower for members of racial/ethnic minority groups traditionally underrepresented in higher education. Just 15 percent of American Indian, 15 percent of Hispanic, and 6 percent of African American ACT-tested high school graduates met ACT's College Readiness Benchmark in Science in 2011, compared to 37 percent of White ACT-tested graduates and 45 percent of Asian/Pacific Islander graduates (Figure 2; ACT 2007, 2011). Of the three groups of underrepresented students, only one has increased its percentage of science-ready ACT-tested graduates by more than 1 percentage point over the past five years. In contrast, the percentage of White science-ready students has increased 4 percentage points during this period and the percentage of science-ready Asian/Pacific Islander students has increased 8 percentage points.

Figure 2: Percentage of ACT-Tested High School Graduates Meeting ACT Science Benchmarks, by Gender and Race/Ethnicity: 2007 and 2011
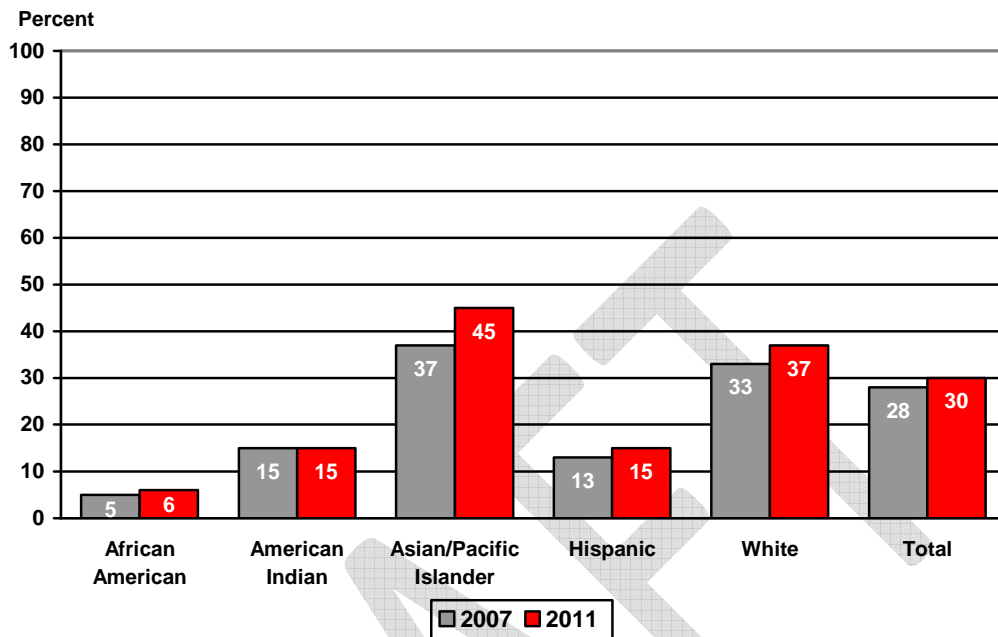

In addition, the academic performance of our middle-school and early high-school students in science suggests that the U.S. is losing its competitive advantage early in the education pipeline. Only 16 percent of 8th-grade students who took ACT's EXPLORE® and 23 percent of 10th-grade students who took ACT's PLAN® in academic year 2010–11 met benchmarks indicating that they are on target to graduate from high school ready for college and career in science (ACT, 2011c).

Results of the National Assessment of Educational Progress (NAEP)[3] also bear out this concern for students at various points along the academic pipeline. Thirty-four percent of 4th graders, 30 percent of 8th graders, and only 21 percent of high school seniors were proficient in science based on NAEP standards in 2009 (U.S. Department of Education, n.d.). Compared to the three previous administrations of the NAEP science assessment at these grade levels, this does represent a steady increase since 1996 for 4th graders and a slight increase for 8th graders (Figure 3; National Center for Education Statistics 2006, U.S. Department of Education n.d.). But while the 2009 results for 12th graders are an improvement over those for 2000 and 2005, they merely return high school seniors to the same percentage proficient that they demonstrated in 1996—meaning that we have made no net progress in more than a decade at improving the science proficiency of our high school graduates.

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[3] Sponsored by the U.S. Department of Education, NAEP provides a nationally representative sample of student academic achievement on mathematics, reading, science, writing, the arts, civics, economics, geography, and U.S. history assessments. National NAEP assessments measure students in grades 4, 8, and 12. NAEP science scores are placed within performance standards and reported as the percentage of students who perform at or above three achievement levels: basic, proficient, and advanced. The percentages reported here indicate the percent of students who scored at or above the NAEP science standard of proficient.

Figure 3: Trends in Percentage of Students Scoring "Proficient" in NAEP Science, by Grade: 1996–2009

Percent
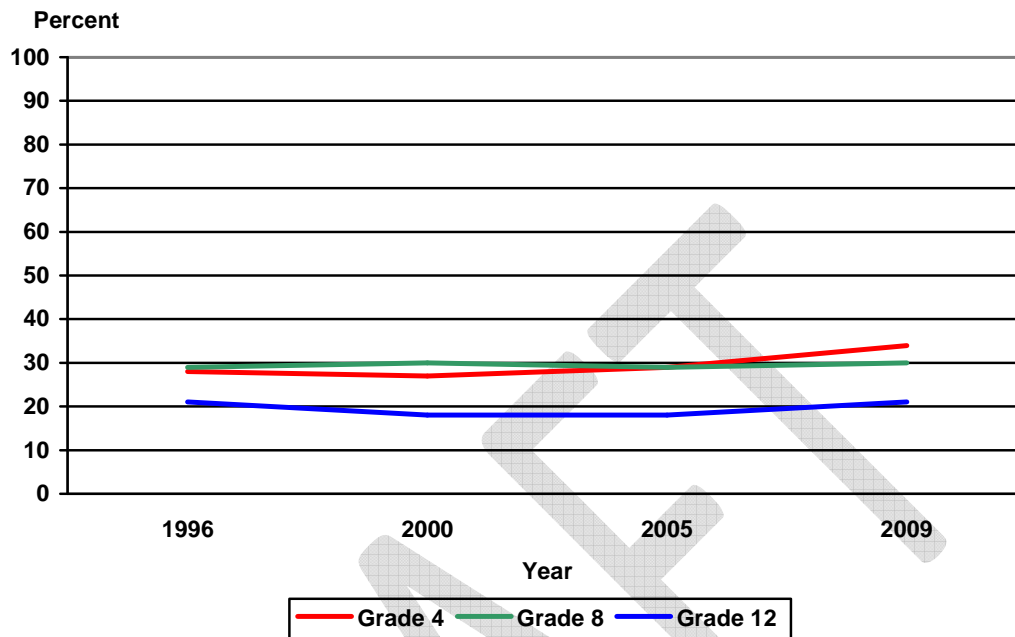
Internationally, the performance of U.S. 15-year-olds was not statistically significantly different from the average performance of all participating countries in a recent Organisation for Economic Co-operation and Development (OECD) assessment of science literacy (OECD, 2010a).[4] This assessment, the Program for International Student Assessment (PISA), identifies six science proficiency levels, with level 6 being the highest. Scoring at level 2 indicates that students can demonstrate the minimum adequate level of basic science competency necessary to understand and manage circumstances involving science in their everyday life. Nearly 20 percent of U.S. students were classified as scoring below Level 2 proficiency; students in 29 of the 64 other participating countries performed better. This is troubling because having almost one-fifth of U.S. 15-year-olds scoring below level 2 reduces the potential pool of future workers in science by at least the same amount.

The recent framework developed by the National Research Council's expert panel as a foundation for new national standards for K–12 science education (*A Framework for K–12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas*) attempts to remedy low levels of college and career readiness in science by emphasizing greater depth in students' understanding of science and encouraging students to engage in scientific inquiry and engineering design as part of the learning process (Robelen, 2011). Among the benefits of the framework is to ensure that all students possess the skills to enter their chosen careers, including careers in science, engineering, and technology (National Research Council of the National Academies, 2011). With so much at stake, it is imperative that the new standards be

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[4] Developed by OECD, the Programme for International Student Assessment (PISA) is a survey conducted every three years and measures the academic skills and knowledge of 15-year-olds in core subject areas, including science. For 2009, 34 OECD member countries and 31 non-OECD partner countries and jurisdictions participated.

rooted in empirical evidence showing the relationship between mastery of the standards and success in postsecondary education and the workplace.

In this report, ACT presents such evidence. The first section presents the research base for ACT's empirical definition of college and career readiness in science. The second section presents ACT's empirical definition and ACT's own research-based list of the essential standards that students need in order to graduate from high school ready for college and career in science. The report concludes by restating the importance of writing and implementing evidence-based standards in preparing all students for postsecondary education and work in science.

ACT hopes that the information and evidence in this report will help guide the developers of the new science standards toward a final product that truly increases the ability of K–12 students in the U.S. to engage with science at a degree of depth that will lead them to the greater scientific innovation and productivity that will restore the nation's global economic competitiveness in scientific and technical career fields.

Empirical Evidence for College and Career Readiness in Science

Many individuals have opinions about what they want students to know and be able to do in order to be labeled as college- and career-ready in science. Relying on expert opinion alone to identify the specific skills and knowledge students need to be ready for college and career is inherently problematic. Merely collating expert opinions of what it takes to be college- and career-ready in science results in an unwieldy amount of material to be taught. Another issue with expert judgment is that not all experts agree, so decisions about what to include and not include become extremely hard to make. Writing standards without incorporating empirical evidence that describes college and career readiness expectations will result in standards that are in fact in conflict with available evidence, which will provide clear validity threats to statements made in the standards documents.

During the development of the Common Core State Standards Initiative in Mathematics and English Language Arts, ACT was one of the key players encouraging the Council of Chief State School Officers and the National Governors Association to require the criterion that each standard must have research behind it in order for that standard to be included in the Common Core. ACT strongly encourages the writers of the Next Generation Science Standards to use the same criterion. In order to support validity arguments regarding the purpose of instruction, empirical evidence is needed that the skills and knowledge being taught are actually linked to achieving college and career readiness. To that end, we outline below the various ACT empirical studies, research, and tools that are most relevant to informing specific decisions on what it takes to be ready for college and career in science.

ACT National Curriculum Survey®

The ACT National Curriculum Survey is nationwide survey of educational practices and expectations conducted by ACT every three years. The survey results provide detailed information on several important fronts. First and foremost, these results provide hard evidence at a "micro" level of what postsecondary instructors of entry-level courses identify as important and necessary for entering college students to know and be able to do to be successful in those courses. In addition, the survey results describe what middle and high school teachers are teaching, and what those instructors report as being most important. By comparing postsecondary and secondary instructors' responses, areas of agreement and disagreement between postsecondary expectations and secondary practice are identified and addressed. The ACT National Curriculum Survey collects a wealth of information about what entering college students should know and be ready to do for credit-bearing college-level coursework and is a powerful tool to make more informed educational decisions about college readiness standards and alignment of those standards with assessment and curriculum. We strongly encourage the writers of the Next Generation Science Standards to use the general findings as well as the item-level information about specific science topics (found in the appendices of the latest ACT National Curriculum Survey document, located at http://www.act.org/research/policymakers/pdf/NationalCurriculumSurvey2009.pdf) to inform decisions around what topics are critical for inclusion.

Some specific findings from the latest survey are clearly relevant to the Next Generation Science Standards. For example, the survey provides evidence that there are currently misalignments between postsecondary instructors' expectation and high school teachers' evaluation of student readiness for postsecondary success. Note that these findings have been repeated over the years (e.g., 2006 and 2009), well after Project 2061's *Benchmarks for Science*

Literacy (1990) and the National Science Education Standards (1996) became available. The ACT National Curriculum Survey asked postsecondary instructors and secondary teachers about how well their state standards and state graduation requirements identify and define what students need to know and be ready to do in their content area. They were also asked how ready students are for college-level work in their content area. The results show that the postsecondary and high school respondents have dramatically different perspectives on these questions: 68 percent of high school teachers reported that their state standards defined "well" or "very well" what students need to know to be ready for college in science, while only 27 percent of postsecondary instructors responded that way. Similarly, 68 percent of high school science teachers felt that their state's graduation requirements prepare students well or very well for college; only 18 percent of postsecondary science instructors shared that view. In fact, 55 percent of postsecondary instructors responded that state graduation requirements prepared students "poorly" or "very poorly." Finally, 92 percent of high school teachers reported that their students were prepared for college-level work in science, whereas 26 percent of postsecondary science respondents reported that incoming students were prepared to do college-level work in science.

Survey results regarding specific topics and skills are also critical for the standards writers to consult. For example, evidence is needed to support the decisions around how much content versus how much science process should be emphasized in the Next Generation standards. The ACT National Curriculum Survey provides strong evidence on this subject. The last several years of the ACT National Curriculum Survey have consistently reported that secondary instruction has been overemphasizing too many content skills. In 2009, among postsecondary science respondents, of the top 21 skills and knowledge rated highest in importance, 10 of the skills were process, 10 were fundamental science content topics, and one was an advanced content topic (understanding and applying the mole concept). Similarly, for junior high/middle school teachers, 19 of the top-rated survey items were process skills and only one was a fundamental science topic. However, among the high school teachers' ratings, only two of the top *fifty* survey items rated highest by high school teachers were process skills; the other 48 were content skills. This is clearly one of the areas of greatest misalignment, and writers of the Next Generation Science Standards need to heed these results carefully. Postsecondary expectations clearly state the process and inquiry skill in science are critical as well as rigorous understanding of fundamental (not advanced) science topics. Therefore, for example, including a great deal of advanced science topics among the Next Generation standards would conflict with available empirical evidence.

The 2009 ACT National Curriculum Survey also identified a critical instructional/expectation gap around reading in science. Postsecondary instructors and high school science teachers were asked how many students are prepared to meet expectations for the required level of reading comprehension in science. Again, the differences in perceptions were staggering. Approximately 62 percent of high school teachers reported that more than half of their students are ready to do college-level reading in science. Postsecondary instructors, however, clearly disagreed, with only 39 percent reporting that most students are ready. Equally interesting is a finding about time spent teaching strategies for how to read science materials. Postsecondary and high school teachers were also asked how much time is spent teaching strategies on how to read science materials. Seventy-one percent of high school teachers and 80 percent of postsecondary instructors reported spending no time or very little time on these strategies. Students are reaching postsecondary courses not meeting reading expectations in science yet not enough is being done to prepare students to read science materials. The Next Generation Science Standards should reflect the need to remedy this deficiency.

ACT College Readiness Benchmarks

A critical piece of setting standards includes knowing how well students need to be able to execute the skills described. To this end, ACT has again taken a unique empirical approach. The ACT College Readiness Benchmarks are the minimum ACT test scores required for students to have a high probability of success in first-year, credit-bearing college courses—English Composition, introductory social sciences courses, Algebra, or Biology. In addition to the Benchmarks for the ACT, there are corresponding EXPLORE and PLAN Benchmarks for use by students who take these programs to gauge their progress in becoming college ready in the eighth and tenth grades, respectively.

Students who meet a Benchmark on the ACT will most likely be able to succeed in their entry level postsecondary course without remediation. Statistically, these students have approximately a 50 percent likelihood of earning a B or better and approximately a 75 percent chance likelihood of earning a C or better in the corresponding college course or courses. Students who meet a Benchmark on EXPLORE or PLAN are likely to have approximately this same chance of earning such a grade in the corresponding college course(s) by the time they graduate high school.

The ACT College Readiness Benchmarks are empirically derived based on the actual performance of students in college. As part of its Course Placement Service, ACT provides research services to colleges to help them place students in entry-level courses as accurately as possible. In providing these research services, ACT has an extensive database consisting of course grade and test score data from a large number of first-year students and across a wide range of postsecondary institutions. These data provide an overall measure of what it takes to be successful in selected first-year college courses. Data from 98 institutions and over 90,000 students were used to establish the Benchmarks. For each course, all colleges that supplied data for that course were included. If a college sent data from more than a single year, only data from the most recent year were included. The numbers and types of college varied by course. Because the sample of colleges in this study is a "convenience" sample (that is, based on data from colleges that chose to participate in ACT's Course Placement Service), there is no guarantee that it is representative of all colleges in the U.S. Therefore, we weighted the sample so that it would be representative of the variety of schools in terms of their selectivity.

The College Readiness Benchmarks for EXPLORE and PLAN were developed using about 150,000 records of students who had taken EXPLORE in the fall of Grade 8, PLAN in the fall of Grade 10, and the ACT in Grades 11 or 12. First, we estimated the probabilities at each EXPLORE and PLAN test score point associated with meeting the appropriate Benchmark for the ACT. We then identified the EXPLORE and PLAN test scores in English, Reading, Mathematics, and Science that corresponded most closely to a 50 percent probability of success at meeting each of the four Benchmarks established for the ACT.

ACT, PLAN, and EXPLORE results give students an indication of how likely they are to be ready for college-level work. The results let students know if they have developed or are developing the foundation for the skills they will need by the time they finish high school. PLAN and EXPLORE results provide an early indication of the student's college-readiness. Students who score at or above the College Readiness Benchmarks in English, mathematics, and science are likely to be on track to do well in entry-level college courses in these subjects. Students scoring at or above the reading benchmark are likely to be developing the level of reading skills they will need in all of their college courses. For students taking EXPLORE and PLAN, this

assumes that these students will continue to work hard and take challenging courses throughout high school.

Science Standards writers can use the Benchmarks as a tool for establishing minimum standards for high school graduation in statewide assessment contexts that are aimed at preparing high school graduates for postsecondary education. Science Standards writers can also use the Benchmarks for EXPLORE and PLAN as a means of evaluating students' early progress toward college readiness so that timely interventions can be made when necessary, or as an educational counseling or career planning tool.

The Benchmark scores in science are fairly high, telling us that the expectations are fairly high in terms of the skills needed to be successful in an entry-level college Biology course.

Text Complexity in Science Literacy

In *A First Look at the Common Core and College and Career Readiness* (ACT, 2010a), ACT examined the current level of student achievement with respect to Common Core Standards Initiative expectations. In this study, more than a quarter-million students in a nationally representative sample represented typical 11th-grade achievement. ACT also analyzed students who were identified as college ready and used them as a proxy performance level for each strand and cluster of the Common Core. Although no current Common Core standards exist with respect to science explicitly, empirical evidence pointed to a highly relevant topic. Specifically, ACT found that too few students (only 31 percent) are able to work with complex text. Also, we found that only 24 percent of students were able to read science materials at a college-ready level. Reading complex text is a requisite skill with respect to science achievement. We strongly encourage the writers of the Next Generation Science Standards to explicitly reference the Common Core Standards in ELA including the Literacy in Science section, and to emphasize the importance of student achievement in this area. Empirical evidence indicates that a lack of literacy in science limits student achievement in science.

WorkKeys Job Profiling and Skills

The WorkKeys workplace readiness assessment system allows for a common language for the job incumbent and the job itself. Not only can each person be classified using one of the four skill levels (Level 3 through Level 6) that make up the score scale along which performance on WorkKeys assessments is reported, but each job can also be classified along the same scale, based on the amount of knowledge and skills required for that job.

These skill levels were established using ACT's job profiling system. In this system, a subject matter expert (typically a job incumbent) familiar with a job is given a task list and asked to rate each task in terms of its importance to the job and the amount of time a typical holder of that job spends doing it. Based on these task ratings, and descriptions of the WorkKeys skill levels, the expert develops a judgment about the skill level necessary for effective job performance.

Note that it is also possible to have a rating that is below 3 for jobs that might not require any level of the given skills. For example, people who work in the human resources department may not require any detailed knowledge of applied technology in order to do their job well. It is also possible to rate a job as requiring skills beyond level 6. For example, a technician at a nuclear plant might require an advanced degree of technological knowledge and skills. It is also important to recognize that even with the same job title there may be disparity in the skill levels required. Someone with the job title "electrician" may be performing fairly simple

tasks, such as repairing small appliances. Another might be designing the electric system for a large manufacturing plant. These would require quite different skill levels, and would be profiled differently.

ACT has a large database where these profiles have been done. Using this data, we can estimate the skill levels needed for most the jobs in the U.S.

The WorkKeys Applied Technology Assessment

The Applied Technology assessment, part of ACT's suite of WorkKeys workplace readiness solutions, is designed to measure the foundational technology skills required for employment. The test does not measure all aspects of science, but rather those that people use when they solve problems with machines and equipment found in the workplace. The test taker is asked about basic principles in four areas; electricity, mechanics, fluid dynamics, and thermodynamics. The questions are not factual in nature, but deal with scientific reasoning as it might apply to job related activities.

The test is scored on a scale from 3 to 6, with each value indicating a specific level of proficiency, increasing as the score increases. The table below gives a general description of the skills necessary to score at each of the levels. Note that each level assumes knowledge from all preceding levels.

Level 3
This level requires knowledge of how basic tools and machines work, application of basic principles to simple problems, diagnosing the potential source of a problem by identifying a clear physical symptom, and arriving at a possible solution by eliminating options that are clearly unsuitable. The key at this level is that the problems are clear, do not contain any extraneous information, have only a single variable, and use only basic technical terms.
Level 4
This level requires knowledge of more complex tools and systems, application of less obvious basic principles for solving problems, eliminating physical symptoms that are unrelated to the problem, and identifying best solutions from a set of options. At this level, the problems may involve more than a single system that work together, extraneous information may be provided, may contain more than a single variable, and less common technical terms may be included
Level 5
This level requires knowledge of complex tools and choosing the best tool for the task at hand. It requires application of two or more principles that may interact in a system, solving more advanced diagnostic problems, and using clues to find the source of a problem. This level will have problems with complex systems with many components, and involve two or more variables. In these problems more technical terms can be used, and these are either explicitly defined or can be inferred from context or diagrams.
Level 6
This level requires solving advanced problems where a variety of faults (mechanical, electrical, fluid, or thermal) could be could lead to the problem. The clues to find the source of the problem are less obvious, and hypotheses must be tested to ensure a correct diagnosis of the problem. These problems will include large amounts of information, and present a variety of possible sources for the problem that interact in ways that makes it difficult to diagnose.

Level 5 is the minimum level at which examinees need to score in order to demonstrate technological competency for jobs that do not require a bachelor's degree but that offer a living wage for a family of four and opportunities for career advancement. Examinees who score at this level are likely to be able to demonstrate the following skills:

- Understand the operation of moderately complex tools and diagnostic equipment, choosing the best tool for the task
- Understand the operation of complex machines and systems

- Apply two or more principles of technology as they interact in moderately complex systems
- Solve moderate and advanced problems
- Eliminate physical symptoms that do not lead to the source of a problem by disregarding extraneous information; use clues to find the source of a problem
- Identify the best solution after eliminating other unsuitable possibilities

Course Rigor in the Science Classroom

An inordinate number of first-year college students struggle to successfully complete first-year credit-bearing courses, even though many of these same students took the "right" courses and received high marks in high school. This trend is especially true for low-income and minority students. Somewhere in the educational system, there is a serious disconnect. There are high schools, however, nullifying this disconnect by preparing students to succeed in those first-year credit-bearing courses.

Study after study shows that when standards are clearly stated, are aligned to fair and valid assessments, and are targeted by instruction, students' chances for success in achieving college readiness are improved. When students are unsure of what is expected of them, their morale suffers along with their performance. The same thing happens when not enough is expected—when their school courses settle for too little. ACT is mindful of these classroom dynamics, and of the overwhelming evidence that students who take rigorous core courses in high school—four years of English, three years of mathematics, three years of laboratory science, and three years of social studies—are more college ready than students who do not.

During the 2003–2004 academic year, ACT and The Education Trust collaborated on a study to determine the courses, the level of rigor, and the instructional practices that are most likely to lead students to college readiness (ACT, & The Education Trust, 2004). The findings are not surprising and for some seem to be common sense. Yet many students do not have access to these characteristics that have such an impact on their eventual level of readiness for postsecondary coursework. The study found that students at these schools were provided with a rigorous, college-oriented curriculum; taught by well-qualified teachers, who have deep conceptual understanding of the content they are teaching and use flexible pedagogical styles; and given the opportunity to receive help outside the classroom when needed.

In the effective high school science classroom these recommendations are standard practice. Students are exposed to key science content presented in an organized and meaningful way. Students are challenged to apply and build on their current knowledge and understanding and make connections to new science content and to life outside of the classroom.

Effective high school science teachers emphasize problem solving, critical thinking, and decision making. Teachers continually ask probing questions that challenges student thinking and allows them to practice the skills of scientific argumentation. Reading, writing, and math are integral to the effective high school science classroom and are routinely interwoven throughout the course, not introduced in isolation.

Students engage in multiple types of learning experiences, stressing high-level reasoning skills and scientific practices. Students practice science by doing science. They are expected to communicate effectively through writing and oral presentation, using the language of science. Opportunities for students to make significant decisions about experiments and to read and carry out scientific research, discerning between conflicting information, are essential in highly effective science courses.

The study also identified some common key findings with respect to science classrooms in schools where students graduated ready for college and career. First, all teachers were qualified to teach science; they all had a college degree in a science discipline, with 88 percent of those teachers have a degree beyond a bachelor's. In the classroom, these teachers were not merely talking heads. They were constantly questioning students as they went over topics. They also made explicit connections between the science content or process being taught and real-life examples. The students were all active participants in the classroom; they were not just sitting listening. In these highly successful classrooms, teachers were indeed talking, but a great deal of lab work was also going on. Approximately 68 percent reported having laboratory activities at least once per week. Some of the labs were student-directed, others were teacher-directed. These experiences all focused on emphasizing the importance of science process. Finally, students in these science classrooms had clear and constant expectations around writing complete and clear explanations. In addition, instructors in Physics and Chemistry emphasized the importance of mathematical analysis, including statistical analyses.

Building on the results of that study and on its own further research, ACT has developed a complement of twelve high school core courses, QualityCore®, aimed at improving classroom instruction and student readiness for postsecondary experiences, including courses in science (Biology, Chemistry, and Physics). QualityCore courses focus on college readiness by identifying specific, clearly delineated course objectives and measures of progress toward meeting those objectives throughout the course. ACT has also developed concordances between QualityCore end-of-course test scores and EXPLORE, PLAN, and ACT test scores so that students who aren't on target to meet the College Readiness Benchmarks are informed and can take action directed toward remedying deficits.

International Benchmarking of Science Performance: College and Career Readiness as an Internationally Competitive Standard

The Common Core State Standards Initiative that aligns U.S. K–12 education with a uniformly higher standard—college and career readiness—across grades and between K–12 and postsecondary systems is a landmark development for U.S. school reform. Driving the design and development of the Common Core State Standards is the definition of college and career readiness developed and empirically established by ACT.

Adopted as of this writing by 43 states and the District of Columbia, the Common Core State Standards are college and career readiness standards for English language arts (which includes reading) and mathematics, and were created to be internationally competitive. Standards from the highest-performing countries on international assessments such as the Programme for International Student Assessment (PISA) were reviewed in detail and used in the developmental process of the Common Core.

Achievement in mathematics, and the ability to read complex scientific texts, are important components in science achievement. These skills are also necessary for entry into jobs in the so-called STEM (science, technology, engineering, and mathematics) fields. In a world that is becoming more competitive through increasing international labor markets and rapid technological advances, the U.S. is facing new challenges to its economic competitiveness. Jobs in a competitive global economy are demanding higher-level skills, higher productivity, and innovation, and other nations are surpassing the U.S. in improving their educational systems to meet these demands. To remain economically competitive with these nations, the U.S. must develop a highly skilled and adaptable workforce capable of meeting productivity demands and adjusting rapidly to changing technologies and an increasingly global environment.

Until recently, no empirical data have been available to examine whether college and career readiness, as defined in the U.S., represents a level of performance that will be competitive with the highest-performing countries around the world. To answer this question, ACT performed an analysis (ACT, 2011a) to identify the PISA scores in mathematics and reading that are equivalent to college- and career-ready mathematics and reading scores on PLAN, ACT's tenth-grade college and career readiness assessment.

The results of this analysis show that the performance standards of U.S. college and career readiness in mathematics (Figure 4) and reading (Figure 5) are indeed internationally competitive, falling well within the range of the highest-performing countries on PISA Mathematics and Reading, respectively.
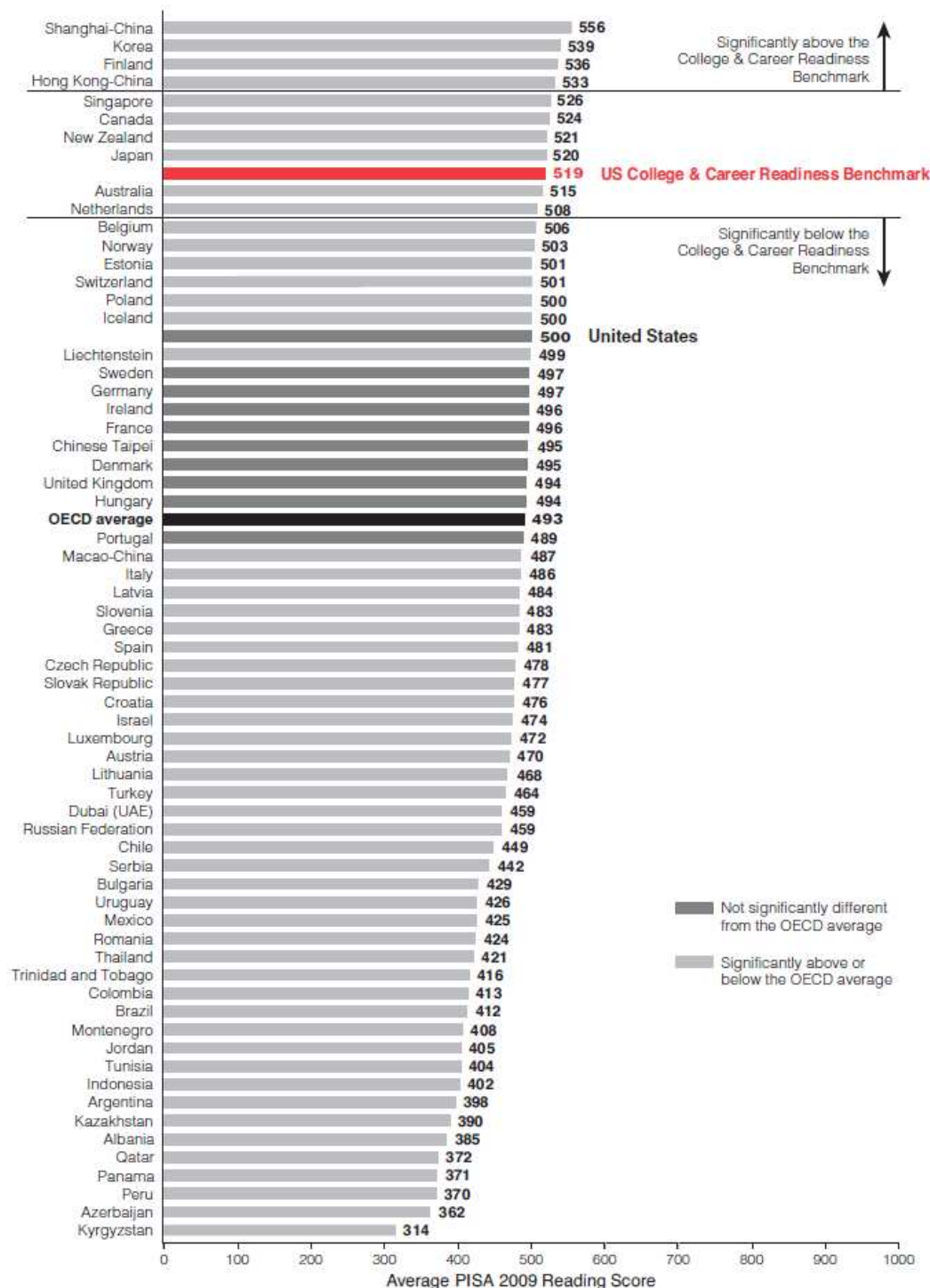
Figure 4: Tenth-Grade College and Career Readiness Performance Benchmark in Mathematics Compared to the Performance of Countries on PISA 2009 Mathematics

Country	Average PISA 2009 Mathematics Score
Shanghai-China	600
Singapore	562
Hong Kong-China	555
Korea	546
Chinese Taipei	543
Finland	541
Liechtenstein	536
Switzerland	534
US College & Career Readiness Benchmark	**530**
Japan	529
Canada	527
Netherlands	526
Macao-China	525
New Zealand	519
Belgium	515
Australia	514
Germany	513
Estonia	512
Iceland	507
Denmark	503
Slovenia	501
Norway	498
France	497
Slovak Republic	497
Austria	496
OECD average	**496**
Poland	495
Sweden	494
Czech Republic	493
United Kingdom	492
Hungary	490
Luxembourg	489
United States	**487**
Ireland	487
Portugal	487
Spain	483
Italy	483
Latvia	482
Lithuania	477
Russian Federation	468
Greece	466
Croatia	460
Dubai (UAE)	453
Israel	447
Turkey	445
Serbia	442
Azerbaijan	431
Bulgaria	428
Romania	427
Uruguay	427
Chile	421
Thailand	419
Mexico	419
Trinidad and Tobago	414
Kazakhstan	405
Montenegro	403
Argentina	388
Jordan	387
Brazil	386
Colombia	381
Albania	377
Tunisia	371
Indonesia	371
Qatar	368
Peru	365
Panama	360
Kyrgyzstan	331

Significantly above the College & Career Readiness Benchmark

Significantly below the College & Career Readiness Benchmark

Not significantly different from the OECD average

Significantly above or below the OECD average

Note: With one exception, the data in this figure are from OECD, *PISA 2009 Results: Executive Summary* (Paris: Author, 2010). The US college and career readiness benchmark value is based on ACT analysis.

Figure 5: Tenth-Grade College and Career Readiness Performance Benchmark in Reading Compared to the Performance of Countries on PISA 2009 Reading

Note: With one exception, the data in this figure are from OECD, *PISA 2009 Results: Executive Summary* (Paris: Author, 2010). The US college and career readiness benchmark value is based on ACT analysis.

ACT's analysis suggests that ensuring that students are college and career ready will effectively put U.S. students on the path toward being internationally competitive with students from the world's highest-performing countries.

ACT's Definition of College and Career Readiness in Science

Basis

ACT bases its definition of college and career readiness in science on a firm foundation of empirical evidence. This definition incorporates and reflects the judgments of ACT measurement experts, science test development specialists, and curriculum and workplace groups. We believe that the ACT definition is not only internally coherent but also fits the framework for learning in science, engineering, and technology described in the National Research Council's *Framework for K–12 Science Education* (National Research Council of the National Academies, 2011).

The ACT definition is an evolutionary product of ACT cofounder E. F. Lindquist's ideas about college entrance exams. Speaking in 1958, Dr. Lindquist prominently included "colleges of engineering and the mechanical arts" in his purview of postsecondary learning and made pointed reference to "the urgent need of raising the level of intellectual competence . . . of our scientists, engineers, and technicians" (Lindquist, 1958, pp. 106–107). By extension, his ideas apply to workplace readiness and training.

Dr. Lindquist recognized the limitations of academic achievement examinations. We are aware that some of the essential signs of college and career readiness in science are hard to quantify: curiosity, receptivity, enthusiasm, passion, wonder. A student's psychological engagement, such as his or her levels of motivation, inspiration, and tenacity, often are difficult to gauge or predict. For this reason, ENGAGE™, a group of ACT behavioral assessments that identifies students who are likely to run into academic trouble and even drop out, has been designed as a simple and reliable method that schools can use to measure these qualities. Such factors are also what applicant interviews and other admissions and hiring procedures are designed to assess—that is, to discern students' levels of such traits as discipline and imagination, and whether students have received from their mentors and teachers a sense of the excitement at scientific discovery and a sense of purpose for careers as science workers and researchers.

Rationale

ACT believes that every student should have a firm foundation of learning in science because such learning is inherently valuable and pleasurable; because it is necessary to informed citizenship in global society; and because it is a practical necessity in our technological age. All these factors are addressed in the National Research Council's *Framework*—for instance in its insistence that all students "have some appreciation for the beauty and wonder of science" (National Research Council of the National Academies, 2011, p. ES-1).

The testimony of the ancient world about the fundamental human yearning for scientific knowledge is well exemplified by the Roman poet Lucretius's *The Nature of Things*. "The mind seeks explanations," says Lucretius, "of the wondrous" (2007, p. 67). The wonder has deepened. As Richard Dawkins has written, "The feeling of awed wonder that science can give us is one of the highest experiences of which the human psyche is capable" (1998, p. x). Ours is a fertile period of scientific writing. Authors of diverse perspectives, from the distinguished naturalist Edward O. Wilson in *Consilience: The Unity of Knowledge* (1998) to the historian Richard Holmes in *The Age of Wonder: How the Romantic Generation Discovered the Beauty and Terror of Science* (2008) offer eloquent accounts of scientific discovery and of how science is interconnected with all other human pursuits. Becoming college and career ready in science

therefore includes becoming ready to produce, recognize, critique, and appreciate new concepts: "it is quite likely that the 21st century will reveal even more wonderful [scientific] insights than those that we have been blessed with in the 20th. But for this to happen, we shall need powerful new ideas, which will take us in directions significantly different from those currently being pursued" (Penrose, 2005, p. 1045).

Development

Education in science, as in other curricular areas in the U.S. over the last century, has undergone polarizing debates about standards and methods (Hirsch, 1996; Ravitch, 2000). In seeking where to turn for guidance, ACT employed scientific methods. Our literature search, consultations, and empirical research have many notable precedents. The quality of educational standards depends on seeking relevant data and up-to-date expert advice from educators. Accordingly, we gather and analyze such data and advice in our ACT National Curriculum Surveys (ACT, 1992, 1998, 2000, 2003, 2007a, 2009).

Concurrently, we analyze data from ACT test results. The ACT Science Test results are generated on the basis of a test developed under Dr. E. F. Lindquist's principle that "the examinations must measure directly the student's *readiness* for college…. That is, they must measure as directly as possible his ability to perform exactly the same kinds of complex tasks that he will have occasion to perform in college and in his later intellectual activities in general" (Lindquist, 1958, p. 108).

In 1997, ACT began an effort to make the test results of our EXPLORE, PLAN, and ACT assessment programs more useful to students, parents, and teachers. This effort yielded ACT's Standards for Transition®. These standards were succeeded by modified standards published in 2005 as ACT's College Readiness Standards™, which remain current today (ACT, 2011b). All the standards are informed by extensive ACT research and data analyses, as described elsewhere in this paper and also in technical manuals for EXPLORE, PLAN, and the ACT (ACT, 2007b, 2007c, 2007d).

The ACT Definition

The Science Test, on the EXPLORE, PLAN, and ACT tests, measures the student's interpretation, analysis, evaluation, reasoning, and problem-solving skills required in the natural sciences. The test assumes that students are in the process of taking the core science course of study (three years or more of science in high school) that will prepare them for college-level work, and have completed a course in Biology and a course in Physical Science and/or Earth Science by the time they take the ACT. The test is made up of various units, each of which consists of some scientific information (the stimulus) and a set of multiple-choice test items.

The use of calculators is not permitted on the Science Test. The scientific information is conveyed on one of three formats:

Data Representation. This format presents students with graphic and tabular material similar to that found in science journals and texts. The items associated with this format measure skills such as graph reading, identifying relationships among variables, and interpretation of information presented in tables.

Research Summaries. This format provides students with descriptions of one or more related experiments. The items focus on the design of experiments and the interpretation of experimental results.

Conflicting Viewpoints. This format presents students with expressions of several hypotheses or views that, being based on differing premises or on incomplete data, are inconsistent with one another. The items focus upon the understanding, analysis, and comparison of alternative viewpoints or hypotheses.

The test items for all three formats require students to recognize and understand the basic features of, and concepts related to, the provided information; to examine critically the relationships between the information provided and the conclusions drawn or hypotheses developed; and to generalize from given information to gain new information, draw conclusions, or make predictions.

The content of the Science Test in the ACT test includes biology, chemistry, physics, and Earth/space sciences (e.g., geology, astronomy, and meteorology). Advanced knowledge in these subjects is not required, but background knowledge covered in general, introductory science courses is needed to answer some of the questions. Advanced mathematical skills are not required, but minimal arithmetic computations may be needed for some questions. The reading portion of the test is concise and clear, so that reading comprehension should not present difficulties. Indeed, the test focuses not on reading comprehension—though examinees do need to read and comprehend the information presented—but rather on reasoning in the context of scientific theory and data. The test goes beyond general reading comprehension by posing the kinds of questions that college students of science must answer in planning, carrying out, and evaluating scientific investigations (e.g., What controls are required? How should the data best be displayed to show trends? What alternative hypotheses or explanations are possible?) and in studying scientific theories (e.g., Which of several theories has the best empirical support? Which theory is the most internally consistent? Which elements of a theory are consistent, or inconsistent, with elements of another theory?). Thus, the test emphasizes scientific reasoning skills over recall of scientific content, skill in mathematics, or reading ability.

The approximate proportions of the ACT Science Test devoted to each of the three formats are shown in the table below.

ACT Science Test 40 items, 35 minutes			
Content Area*	**Format**	**Proportion of Test**	**Number of Items**
Biology	Data Representation	.38	15
Chemistry	Research Summaries	.45	18
Earth/Space Science	Conflicting Viewpoints	.17	7
Physics			
Total		1.00	40
Score reported: Total test score (40 items)			

*All four content areas are represented in the test. The content areas are distributed over the different formats in such a way that at least one unit, and no more than two units, represents each content area.

ACT's College Readiness Standards

ACT's College Readiness Standards are statements that describe what students who score in certain score ranges are *likely* to know and to be able to do. The statements are generalizations based on the performance of many students scoring in these score ranges. College Readiness Standards have not been developed for students whose scores fall in the lowest range because these students, as a group, do not demonstrate skills similar to each other consistently enough to permit useful generalizations. The standards are cumulative, meaning

that students typically can demonstrate the skills and knowledge described in the score ranges below the range in which they scored. The College Readiness Standards have undergone rigorous and detailed review by science educators at the middle school, high school, and postsecondary levels and have been favorably received in the educational community.

ACT's College Readiness Standards in science are given in the table below, accompanied by a list of science topics typical of science courses and representative of the topics on the ACT Science Test. Standards in the 24–27 score range reflect those skills that a student who meets the ACT College Readiness Benchmark for Science is likely to know and be able to demonstrate, in addition to all those that fall within the lower score ranges. The first four rows of standards, therefore, represent the essential standards that students need to master in order to be at a minimal level of college and career readiness in science. Skills in the fifth and sixth rows represent advanced levels of achievement above and beyond those needed to demonstrate the minimal level of college and career readiness.

College Readiness Standards — Science

	Interpretation of Data	Scientific Investigation	Evaluation of Models, Inferences, and Experimental Results
13–15	Select a single piece of data (numerical or nonnumerical) from a simple data presentation (e.g., a table or graph with two or three variables; a food web diagram) Identify basic features of a table, graph, or diagram (e.g., headings, units of measurement, axis labels)		
16–19	Select two or more pieces of data from a simple data presentation Understand basic scientific terminology Find basic information in a brief body of text Determine how the value of one variable changes as the value of another variable changes in a simple data presentation	Understand the methods and tools used in a simple experiment	
20–23	Select data from a complex data presentation (e.g., a table or graph with more than three variables; a phase diagram) Compare or combine data from a simple data presentation (e.g., order or sum data from a table) Translate information into a table, graph, or diagram	Understand the methods and tools used in a moderately complex experiment Understand a simple experimental design Identify a control in an experiment Identify similarities and differences between experiments	Select a simple hypothesis, prediction, or conclusion that is supported by a data presentation or a model Identify key issues or assumptions in a model
24–27	Compare or combine data from two or more simple data presentations (e.g., categorize data from a table using a scale from another table) Compare or combine data from a complex data presentation Interpolate between data points in a table or graph Determine how the value of one variable changes as the value of another variable changes in a complex data presentation Identify and/or use a simple (e.g., linear) mathematical relationship between data Analyze given information when presented with new, simple information	Understand the methods and tools used in a complex experiment Understand a complex experimental design Predict the results of an additional trial or measurement in an experiment Determine the experimental conditions that would produce specified results	Select a simple hypothesis, prediction, or conclusion that is supported by two or more data presentations or models Determine whether given information supports or contradicts a simple hypothesis or conclusion, and why Identify strengths and weaknesses in one or more models Identify similarities and differences between models Determine which model(s) is(are) supported or weakened by new information Select a data presentation or a model that supports or contradicts a hypothesis, prediction, or conclusion
28–32	Compare or combine data from a simple data presentation with data from a complex data presentation Identify and/or use a complex (e.g., nonlinear) mathematical relationship between data Extrapolate from data points in a table or graph	Determine the hypothesis for an experiment Identify an alternate method for testing a hypothesis	Select a complex hypothesis, prediction, or conclusion that is supported by a data presentation or model Determine whether new information supports or weakens a model, and why Use new information to make a prediction based on a model
33–36	Compare or combine data from two or more complex data presentations Analyze given information when presented with new, complex information	Understand precision and accuracy issues Predict how modifying the design or methods of an experiment will affect results Identify an additional trial or experiment that could be performed to enhance or evaluate experimental results	Select a complex hypothesis, prediction, or conclusion that is supported by two or more data presentations or models Determine whether given information supports or contradicts a complex hypothesis or conclusion, and why

Science College Readiness Standards are measured in the context of science topics students encounter in science courses. These topics may include:		
Life Science/Biology	**Physical Science/Chemistry, Physics**	**Earth & Space Science**
• Animal behavior • Animal development and growth • Body systems • Cell structure and processes • Ecology • Evolution • Genetics • Homeostasis • Life cycles • Molecular basis of heredity • Origin of life • Photosynthesis • Plant development, growth, structure • Populations • Taxonomy	• Atomic structure • Chemical bonding, equations, nomenclature, reactions • Electrical circuits • Elements, compounds, mixtures • Force and motions • Gravitation • Heat and work • Kinetic and potential energy • Magnetism • Momentum • The Periodic Table • Properties of solutions • Sound and light • States, classes, and properties of matter • Waves	• Earthquakes and volcanoes • Earth's atmosphere • Earth's resources • Fossils and geological time • Geochemical cycles • Groundwater • Lakes, rivers, oceans • Mass movements • Plate tectonics • Rocks, minerals • Solar system • Stars, galaxies, and the universe • Water cycle • Weather and climate • Weathering and erosion

In the twenty-first century U.S., a clear consensus has formed supporting the proposition that college readiness and workforce readiness are similar:

> Studies of the skills and knowledge that employers need in the workplace show with increasing clarity that their expectations look very much like those in higher education. (Somerville & Yi, 2002, p. 4)

> In the business world, there is little doubt that the skills needed for success in work and in college are now converging. (Barth, 2003, p. 16)

> No longer do students planning to go to work after high school need a different and less rigorous curriculum than those planning to go to college. (The American Diploma Project, 2004, pp. 8–9)

Scientific literacy is widely perceived as a prerequisite to success in college and in the workplace. ACT's research supports that perception. Attainment of the skills and knowledge described in ACT's College Readiness Standards for science brings with it not only the prospect of academic and career success, but also the promise of personal fulfillment and responsible citizenship. We believe that the ACT definition of college and career readiness in science provides information that has both practical and inherent value.

Conclusion

As stated throughout this report, it is crucial that a new generation of K–12 science standards be firmly grounded in evidence that the standards to be taught in K–12 will actually help prepare students for postsecondary education in science and for careers. Decades of ACT research into the relationship between what students know and can do in school and their degree of success in life after high school provides just such an evidentiary foundation.

We strongly encourage the writers of the Next Generation Science Standards to take advantage of ACT's expertise during all stages of the standards-development process. Just as ACT research helped establish the empirical basis for the Common Core State Standards in Mathematics and English Language Arts, so also can it provide the Next Generation Science Standards with the evidence needed to tie the new standards to college and career readiness in science. ACT stands ready to assist the Next Generation Science Standards team in its important work of ensuring that U.S. students gain the strong underpinning in science and technology skills that they will need in order to consolidate and extend the nation's economic competitiveness in science into the future.

References

ACT. (1992). *Content validity of ACT's educational achievement tests.* Iowa City, IA: Author.

ACT. (1998). *Maintaining the content validity of ACT's educational achievement tests.* Iowa City, IA: Author.

ACT. (2000). *Content validity evidence in support of ACT's educational achievement tests: ACT's 1998–1999 National Curriculum Survey.* Iowa City, IA: Author.

ACT. (2003). *Content validity evidence in support of ACT's educational achievement tests: ACT National Curriculum Survey 2002–2003.* Iowa City, IA: Author.

ACT. (2006). *Ready for college and ready for work: Same or different?* Retrieved August 3, 2011, from http://www.act.org/research/policymakers/pdf/ReadinessBrief.pdf

ACT. (2007). *ACT high school profile report: The graduating class of 2007—National.* Iowa City, IA: Author.

ACT. (2007a). *ACT National Curriculum Survey 2005–2006.* Iowa City, IA: Author.

ACT. (2007b). *ACT technical manual.* Iowa City, IA: Author.

ACT. (2007c). *EXPLORE technical manual.* Iowa City, IA: Author.

ACT. (2007d). *PLAN technical manual.* Iowa City, IA: Author.

ACT. (2009). *ACT National Curriculum Survey 2009.* Iowa City, IA: Author.

ACT. (2010a). *A first look at the Common Core and college and career readiness.* Retrieved August 23, 2011, from http://www.act.org/research/policymakers/pdf/FirstLook.pdf

ACT. (2010b). *What are ACT's College Readiness Benchmarks?* Retrieved August 3, 2011, from http://www.act.org/research/policymakers/pdf/benchmarks.pdf

ACT. (2011a). *Affirming the goal: Is college and career readiness an internationally competitive standard?* Retrieved August 23, 2011, from http://www.act.org/research/policymakers/pdf/AffirmingtheGoal.pdf

ACT. (2011b). *College Readiness Standards for EXPLORE, PLAN, and the ACT.* Iowa City, IA: Author.

ACT. (2011c). *The condition of college and career readiness 2011.* Iowa City, IA: Author.

ACT. (2011d). *WorkKeys Applied Technology job skill comparison chart.* Retrieved August 23, 2011, from http://www.act.org/workkeys/charts/tech.html

ACT & The Education Trust. (2004). *On course for success: A close Look at selected courses that prepare all students for college.* Retrieved August 23, 2011, from http://www.act.org/research/policymakers/pdf/success_report.pdf

American Diploma Project. (2004). *Ready or not: Creating a high school diploma that counts*. Washington, DC: Achieve, Inc. Retrieved August 23, 2011, from http://www.achieve.org/files/ADPreport_7.pdf

Association of American Colleges and Universities. (2008). *College learning for the new global Century*. Retrieved July 29, 2011, from http://www.aacu.org/leap/documents/GlobalCentury_ExecSum_3.pdf

Barth, P. (2003). A common core curriculum for the new century. *Thinking K–16, 7*(1), 3–25. Retrieved August 23, 2011, from http://www.edtrust.org/sites/edtrust.org/files/publications/files/k16_winter2003_0.pdf

Brookings Institution. (2010). *The 2010 Brown Center report on American education: How well are American students learning?* Retrieved July 21, 2011, from http://www.brookings.edu/~/media/Files/rc/reports/2011/0111_naep_loveless/0111_naep _loveless.pdf

Carnevale, A. P., & Rose, S. J. (n.d.). *The undereducated American.* Retrieved August 3, 2011, from http://www9.georgetown.edu/grad/gppi/hpi/cew/pdfs/undereducatedamerican.pdf

Dawkins, R. (1998). *Unweaving the rainbow: Science, delusion and the appetite for wonder*. Boston: Houghton Mifflin.

Hirsch, E. D., Jr. (1996). *The schools we need and why we don't have them*. New York: Doubleday.

Holmes, R. (2008). *The age of wonder: How the Romantic generation discovered the beauty and terror of science.* New York: Pantheon.

Lacey, T. A., & Wright, B. (2010). *Occupational employment projections to 2018.* Retrieved August 3, 2011, from http://www.bls.gov/opub/mlr/2009/11/art5full.pdf

Lindquist, E. F. (1958, November). The nature of the problem of improving scholarship and college entrance examinations. *Proceedings of the Invitational Conference on Testing Problems*. Educational Testing Service: 104–113. Retrieved August 23, 2011, from http://www.eric.ed.gov/PDFS/ED181053.pdf

Lucretius. (2007). *The nature of things*. A. E. Stallings (Trans.). London: Penguin. (Original work written 50 BCE)

National Center for Education Statistics. (2006). *The Nation's report card: Science 2005.* Washington, DC: U.S. Department of Education.

National Research Council of the National Academies. (2011). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Retrieved August 3, 2011, from http://www.nap.edu/catalog.php?record_id=13165

National Science Foundation. (2010). *Key science and engineering indicators: 2010 digest.* Retrieved August 3, 2011, from http://www.nsf.gov/statistics/digest10/trends.cfm#1

OECD. (2010). *PISA 2009 results: Executive summary.* Paris: Author.

OECD. (2010a). *PISA 2009 at a glance.* Retrieved August 3, 2011, from http://www.pisa.oecd.org/dataoecd/31/28/46660259.pdf

Penrose, R. (2005). *The road to reality: A complete guide to the laws of the universe*. New York: Alfred A. Knopf.

Ravitch, D. (2000). *Left back: A century of failed school reforms*. New York: Simon & Schuster.

Robelen, E. W. (2011). *New science framework paves way for standards. Education week, 30*(7). Retrieved August 3, 2011, from http://www.edweek.org/ew/articles/2011/07/19/37science.h30.html

Somerville, J., & Yi, Y. (2002, October). *Aligning K–12 and postsecondary expectations: State policy in transition*. Retrieved August 23, 2011, from http://www.nashonline.org/ALIGNreport.pdf

U.S. Department of Education. (2010), College and career-ready students. Retrieved July 12, 2011, from http://www2.ed.gov/policy/elsec/leg/blueprint/publication_pg4.html#part4

U.S. Department of Education. (n.d.). *2009 science: Summary of major findings.* Retrieved August 3, 2011, from http://nationsreportcard.gov/science_2009/summary.asp

Wilson, E. O. (1998). *Consilience: The unity of knowledge.* New York: Vintage.